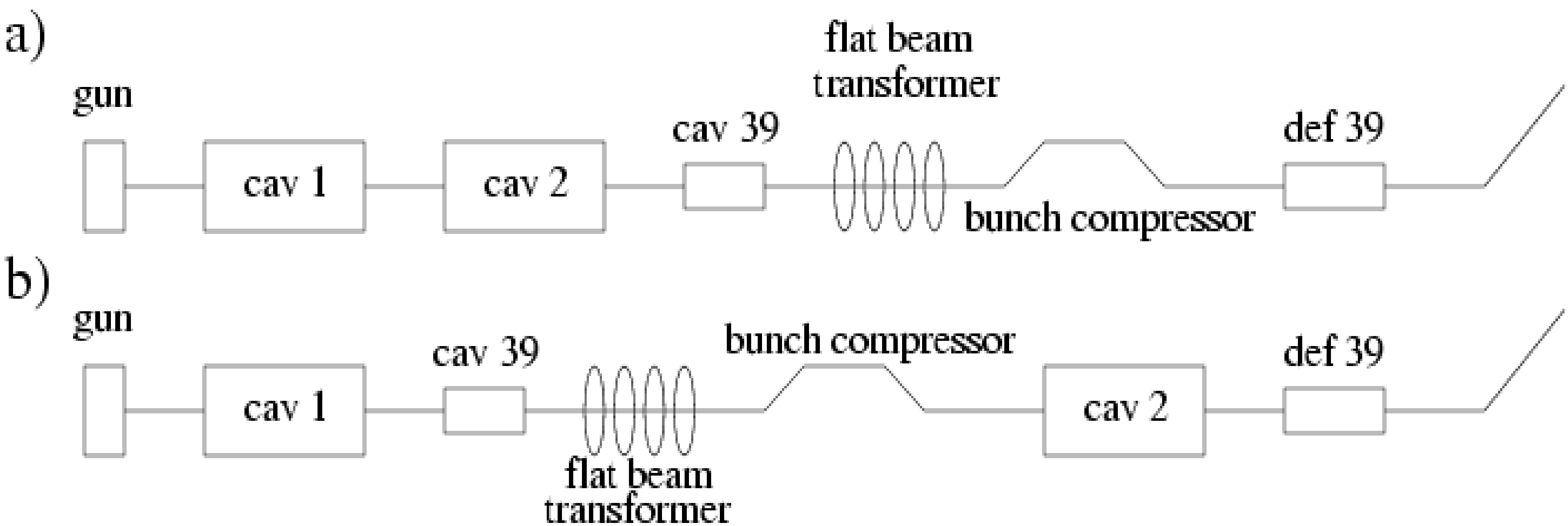
P^2, oct 21th 2003

Some thoughts on A0 upgrade: beam dynamics considerations

My understanding of requirements:

- Have the TESLA high gradient cavity installed (added to the present set-up?)
- Design should include room for both 3.9 Ghz accelerating and deflecting mode cavities
- Design should still allow the generation of flat beam (if possible compressed flat beam)

The two main choices (other suggestions welcome!):



Some thoughts on A0 upgrade: beam dynamics considerations

- The new design should address bugs in the present design
- On big present problem is the compression scheme used:

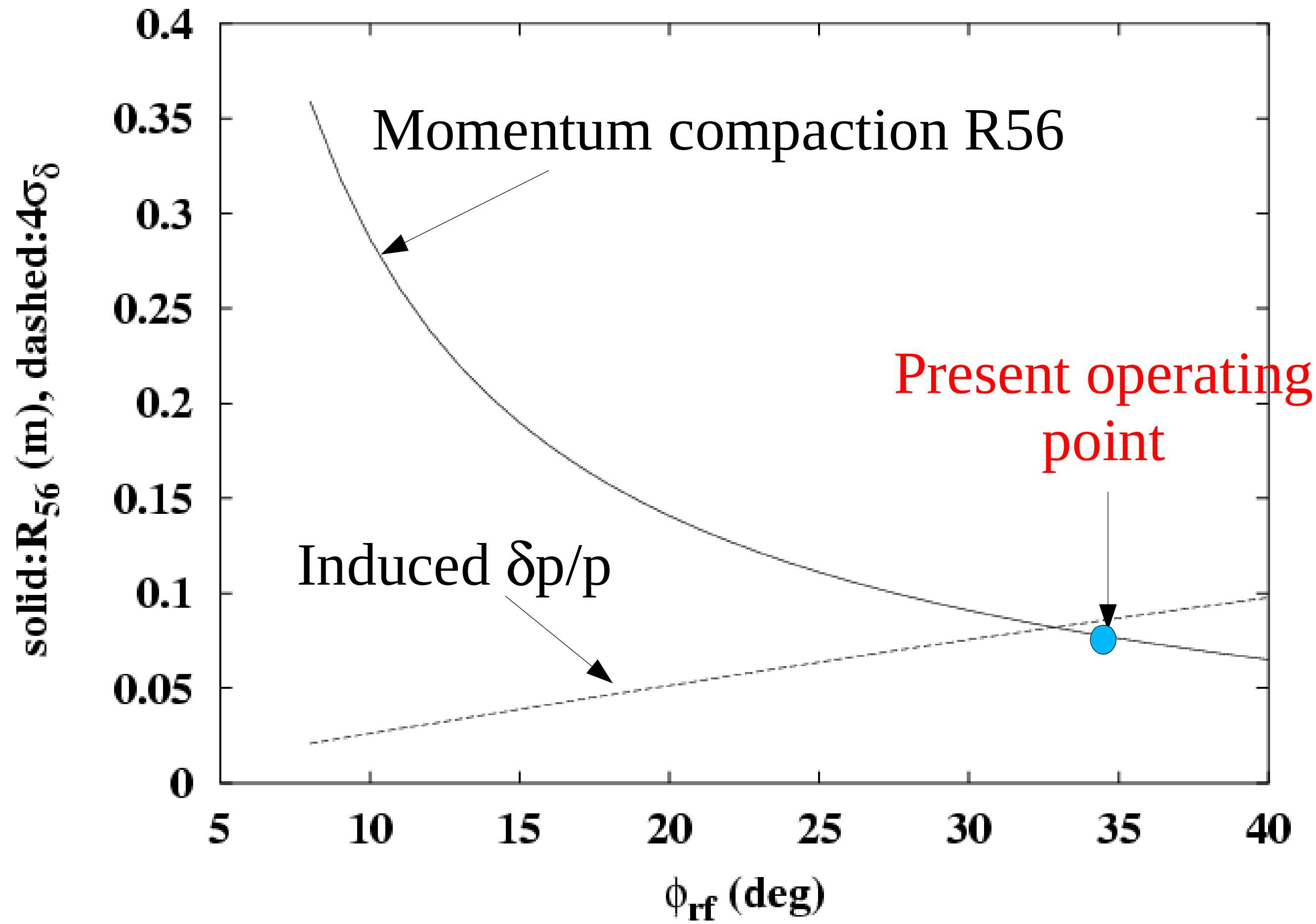


Fig.: required bunch compressor R56 versus phase of the TESLA cavity based on simple analytical estimate

Energy spread presently large: ~ 10 % full may have bad consequence...

Impact of δp/p on round-to-flat beam (R2FB) transformer

- chromatic effect on studied for the present A0 set-up

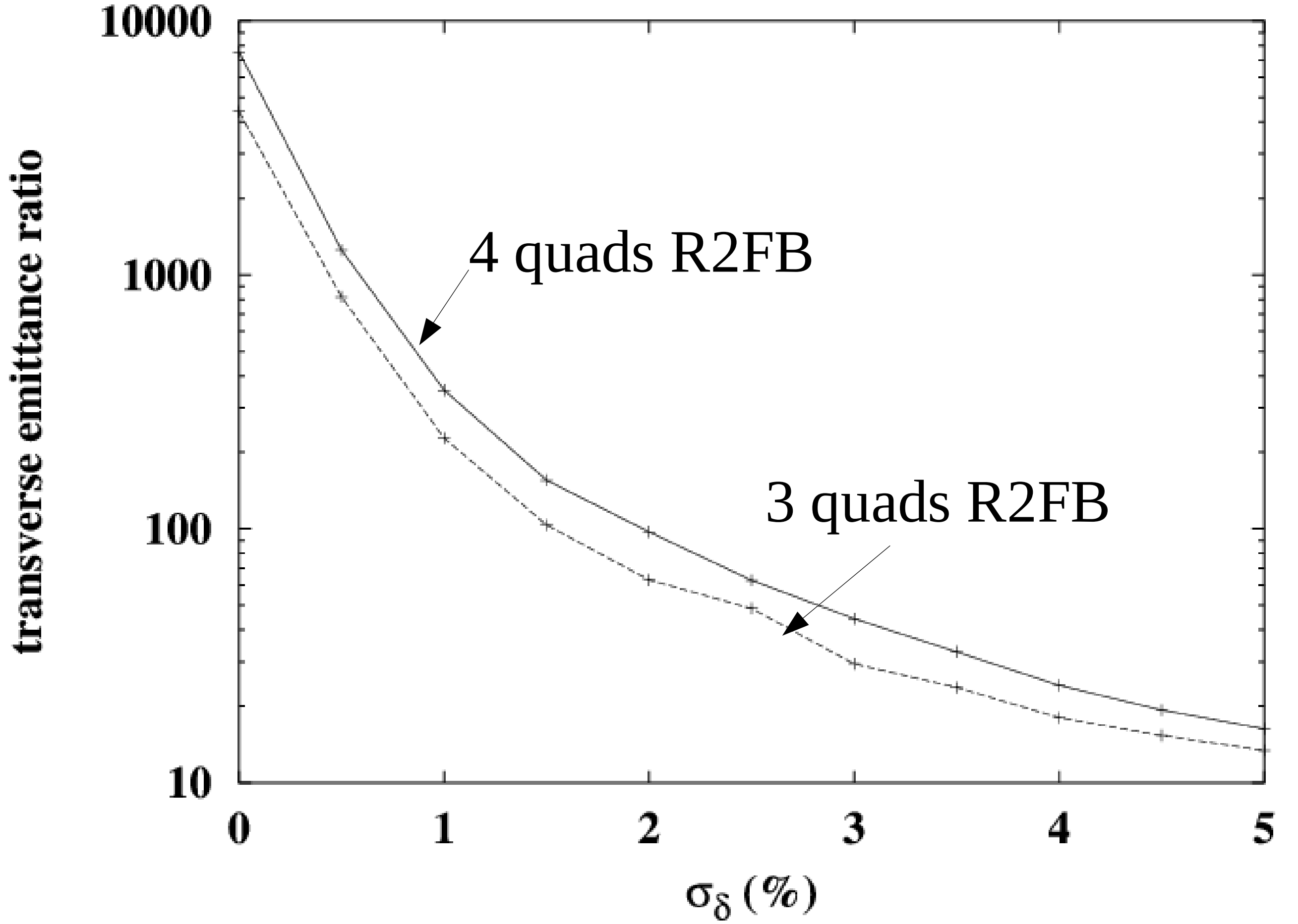
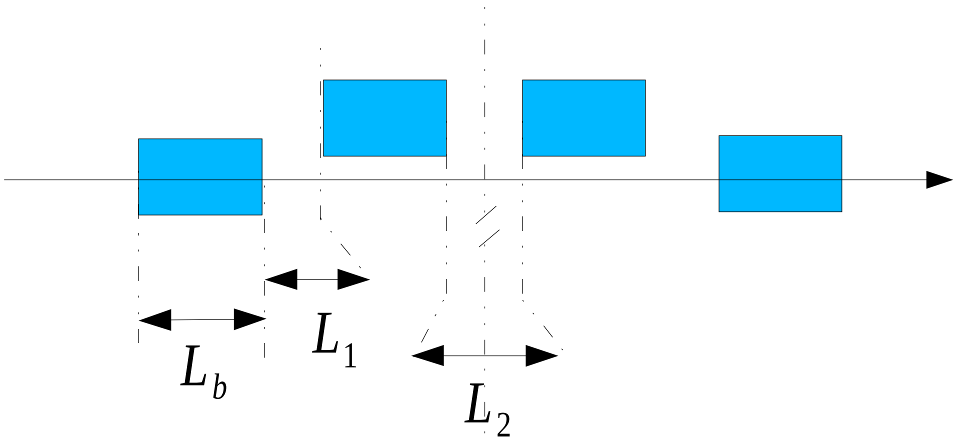


Fig.: impact of rms relative energy spread on the flat beam emittance ratio

➔total momentum spread budget < 1 % (to get $\varepsilon_x / \varepsilon_y \geqslant 100$)

A quick simple fix for the bunch compressor



The momentum compaction is given by:

$$R_{56} = 4L_b\left(\frac{1}{\cos\psi} - \frac{\psi}{\sin\psi}\right) + 2L_1\frac{\sin^2\psi}{\cos^3\psi}$$

to keep moderate angle 23 deg, a bend length of 0.3 m, I come up with L_1=0.5 m to get a R_{56}~0.25 m.

The price of this simple fix is LENGTH of the compressor. New total length is:

*4*0.3+2*0.5+0.3 =2.5 meters.*

Note: Now BC1 length is 1.33 m

Nota: I took L_2=0.3 m so that we can introduce a viewer at the compressor symmetry point to measure energy and set the bending angle properly.

Discussion of the two option (shown in slide 1)

<u>The "must" for any option:</u>

→ The 3.9 GHz deflecting cavity (def39) should be downstream of the bunch compressor to allow time resolve measurements of beam properties

→ Proper optics should be added before def39 to allow rf-measurements (e.g. field uniformity along the cavity aperture etc...)

→ The 3.9 Ghz accelerating cavity (acc39) must be located before the bunch compressor to allow compression of linearized longitudinal phase space and related experiments

→ The R2FB transformer must be located upstream from the compressor if we want to be able to compress flat beam

<u>Differences between option a and b (of slide 1):</u>

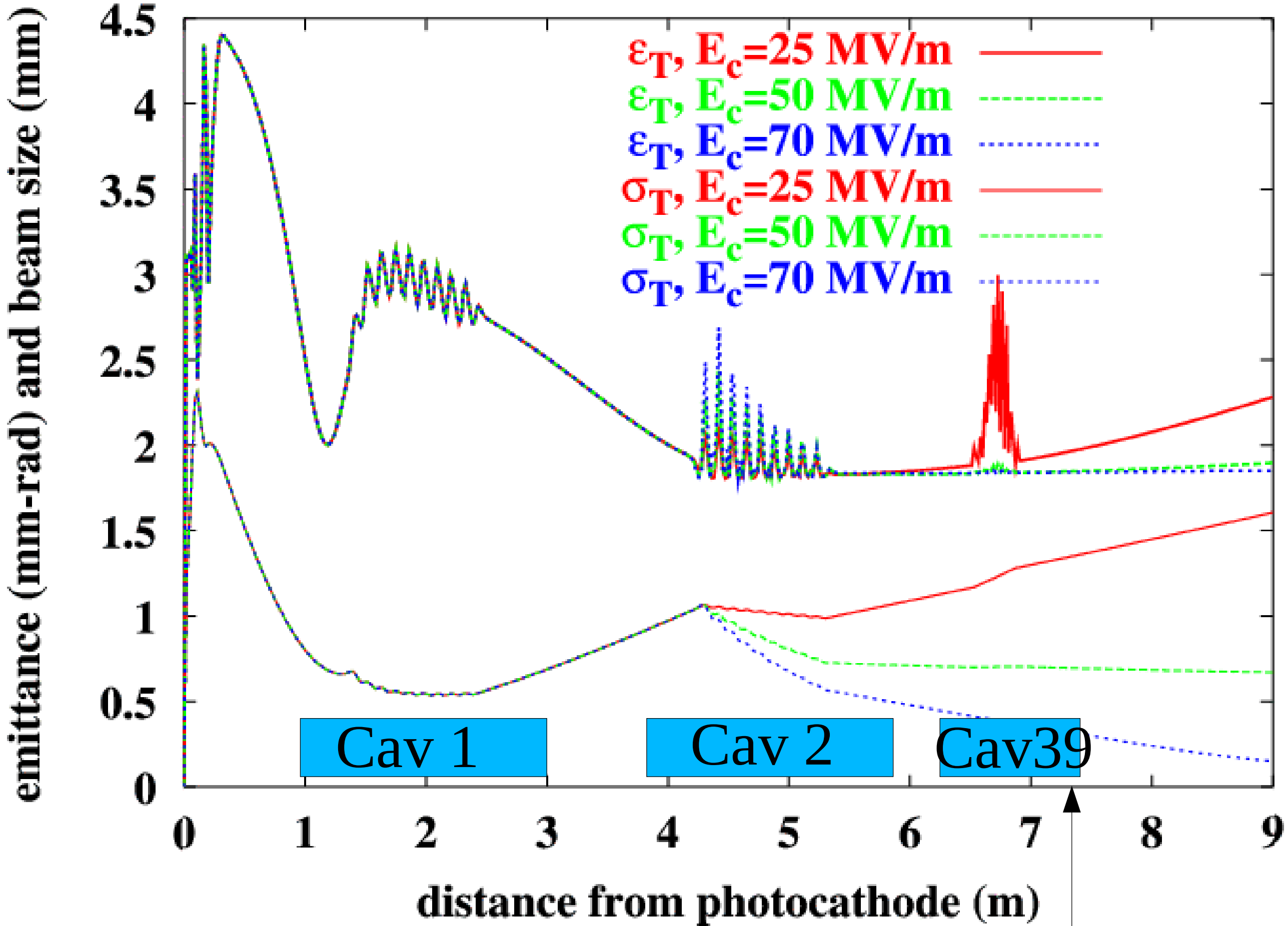
→ since the required accelerating voltage on cav39 for the linearization of the phase space is $V_{cav39}=1/9(V_{cav1}+V_{cav2})$, option b requires a lower voltage on cav39. However the accelerating voltage on the cav39 has been specified to be ~5 MV so $(V_{cav1}+V_{cav2})\leqslant 45$ MV

→ option b would generate lower energy total spread but the compression occurs at lower energy and space charge forces are thus stronger that in option a

OPTION <u>A</u> IS PREFERABLE

Study of option a: {cav1, cav2, cav39} nom. Setup

Emittance evolution along z
cav1=25 MV/m peak field
cav2 =25, 50, 70 MV/m peak field



Accelerating section ends-up at 7.3 m from photo-cathode

Study of option a: {cav1, cav2, cav39} nom. Setup

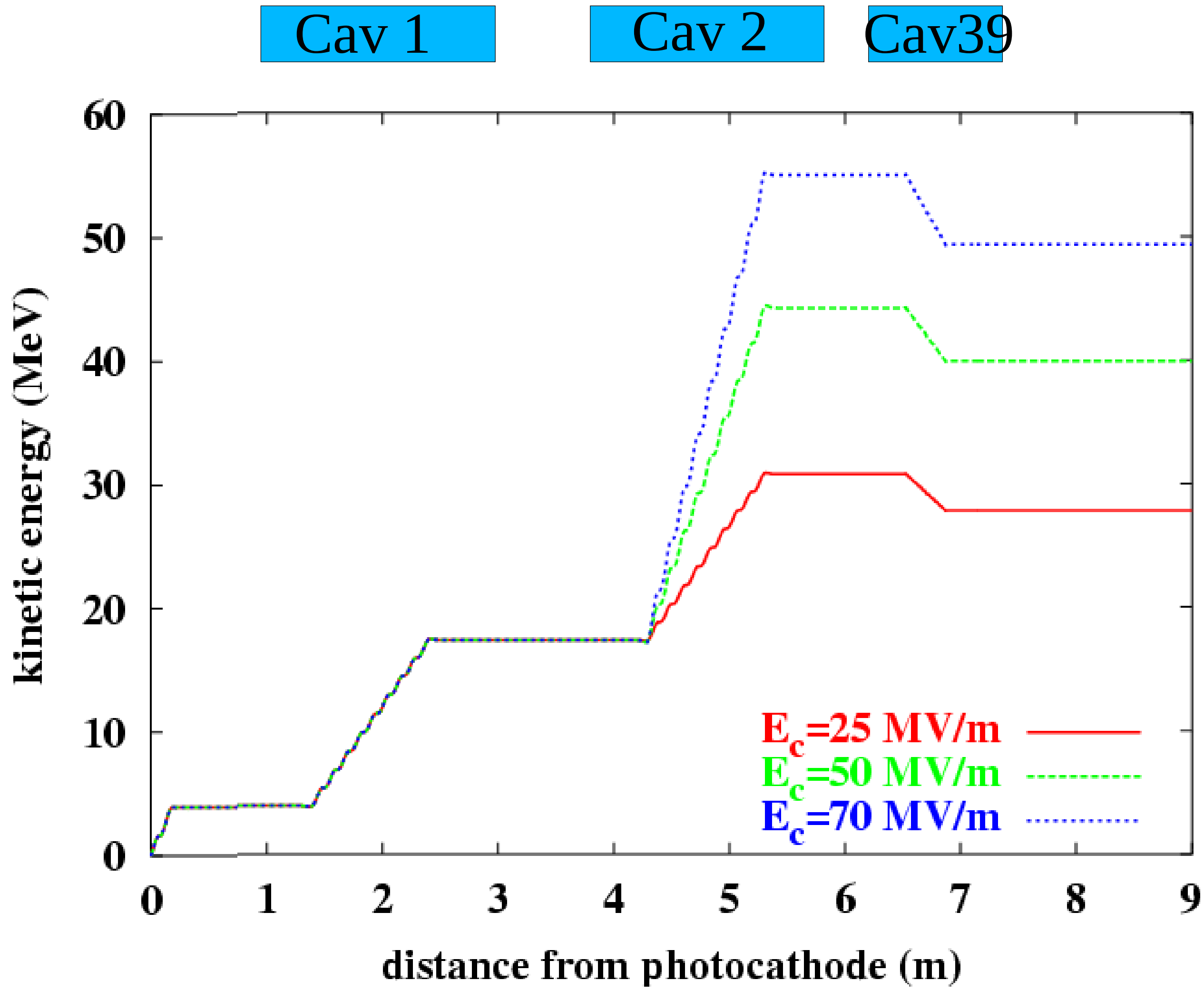
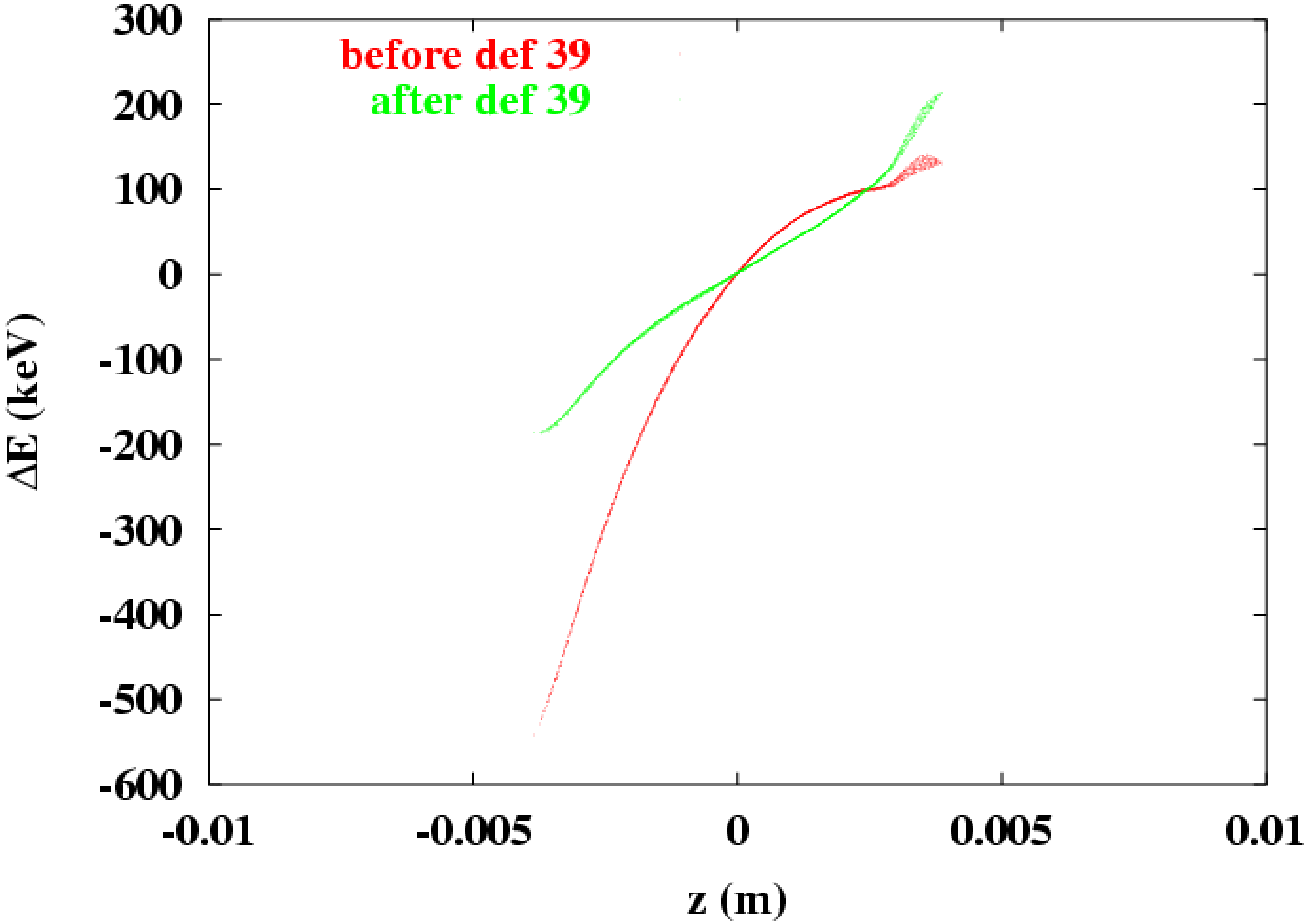


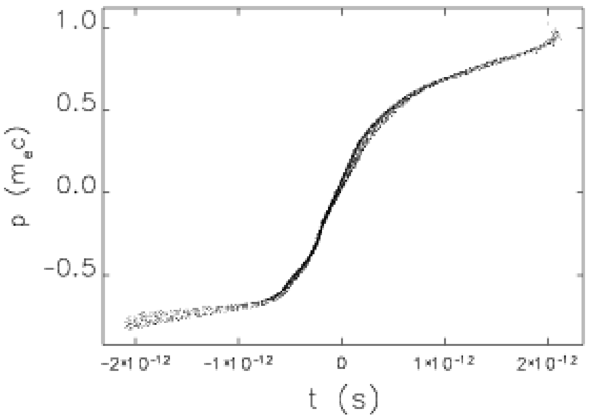
Fig. Energy gain along z for various operating points of the high gradient TESLA cavity

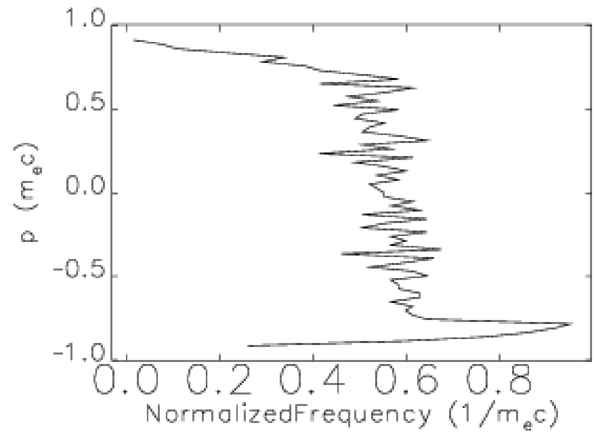
Study of option a: effect of def 39 on $(z,\delta p/p)$ space

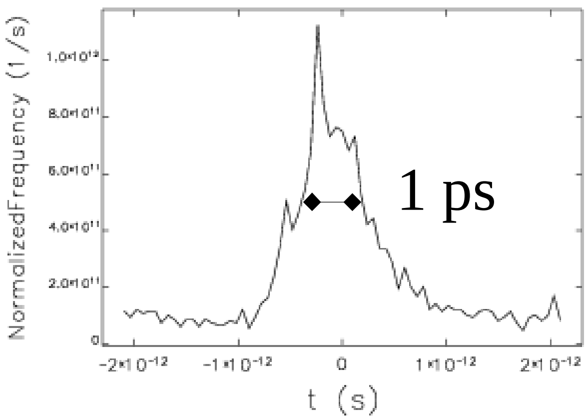


Study of option a: compression (single particle dynamics!)

Longitudinal phase space downstream of bunch compressor for nominal set of the high gradient cavity (25 MV/m average acc. Grad.)







Smaller bunch length are possible (not at maximum compression yet) but need to study this with CsrTrack tracking code

The two cavities are operated -14 deg resulting in a total relative energy spread of 0.7 % well within the δp/p budget for avoiding significant chromatic emittance dilution

"Hand waving" estimate of the required length for the total accelerator

The ~knowns:

Gun to end of 3.9 Ghz ends at 7.3 m
flat beam adapter + ~2.0 m (need work + limit from power supply?)
chicane + ~2.5 m

= 11.8 meters from cathode surface

then many unknowns (at least to me!):

optics BC to def39 + 1 (need work + limit from power supply?)
deflecting cavity + ~1.5 (need exact length)
optics def39 to spectro + 1 (need work + limit from power supply?)

= 3.5 meters

TOTAL length is : 15.3 m so ~4.5 meters are usable to instal experiments

Don and I measure the end-wall to be at 19.7 m from actual position of photocathode